Appl. No.09/942,628
Amdt. dated June 21, 2005
Reply to Office action of March 22, 2005
Atty. Docket No. AP1102US

Amendments to the Specification:

Please replace the paragraph beginning at page 1, line 31 with the following amended paragraph:

-- VDSL technology typically uses discrete multi-tone (DMT) and ~~Frequency Division Multiplexing (FDM)~~ Fast Fourier Transform (FFT) technologies. In such systems the available bandwidth is used to carry multiple channels of information and a Fast Fourier Transform (FFT) is typically used to convert frequency domain modulated signals into time domain signals. In this technology a transmitter at the local Neighborhood Termination (NT) receives the data from the central office and converts it through an Inverse FFT function into a form for downloading on the twisted copper pair. At the receiver ~~an Inverse~~ a Fast Fourier Transform [[~~(IFFT)~~]] function is used to obtain the original frequency signal. For large channel bandwidths with a large number of subchannels being used such as in the VDSL application, the FFT size, by necessity, is very large. This introduces two main drawbacks which make the DMT application in VDSL almost impractical. The first is that the FFT size is very large and this impacts from a chip design perspective and the second is that the execution of the function will take a long time. Accordingly, there is a requirement to develop a system for the efficient implementation of an FFT in ~~DMT/FDM~~ DMT applications. --

Please replace the paragraph beginning at page 2, line 19 with the following amended paragraph:

-- Therefore in accordance with a [[fist]] first aspect of the present invention there is provided a system for implementing a Fast Fourier Transform (FFT) in a broad bandwidth, high data rate communications application, the system comprising: means to divide the bandwidth into subbands; and means to implement the FFT separately for each subband using, for each subband, a respective one of a plurality of different FFTs. --

Please replace the paragraph beginning at page 2, line 23 with the following amended paragraph:

-- In accordance with a second aspect of the present invention there is provided a method of implementing a Fast Fourier Transform (FFT) in a broad bandwidth, high data rate communications application, the method comprising: dividing the bandwidth into sub-bands; and implementing the FFT separately for each sub-band using, for each subband, a respective one of a plurality of different FFTs. --

Please replace the paragraph beginning at page 2, line 31 with the following amended paragraph:

-- FIG. 1 illustrates a typical transmit signal spectrum in [[an]] a "prior art" FDM system; --

Please replace the paragraph beginning at page 3, line 11 with the following amended paragraph:

-- In a typical DMT based system, an N point IFFT is used to transform N frequency subchannel carriers, with quadrative amplitude modulation (QAM) modulated data, into N point time domain samples. [[~~FIG. 1~~]] Figure 1, labelled "PRIOR ART", shows a typical transmit signal spectrum when frequency division multiplexing (FDM) is being used. The implementation is relatively simple: data is first modulated onto subchannel carriers using QAM modulation and the N point IFFT is applied. At the receiver end, FFT is applied first and then QAM demodulation is used to get the original data. The transmitter and receiver block diagrams are shown in FIG. 2. --

Please replace the paragraph beginning at page 3, line 19 with the following amended paragraph:

-- The problem with the above implementation is that both computation and chip size will be very large. In typical VDSL ~~application~~ applications, for example, N=8192. Also, [[~~since~~]] if FDM

is used in VDSL, only ~~approximate~~ approximately half of the bandwidth is used for either down stream or up stream data transmission. Performing IFFT on the whole frequency band is a waste for both computation and clip size. In the following, a modification scheme is used where ~~a couple of~~ several small size FFTs are used instead of one big FFT. --

Please replace the paragraph beginning at page 3, line 26 with the following amended paragraph:

-- Figure 3 shows one implementation of data transmission according to one aspect of the invention, where the total frequency band (B) is divided into M sections each with bandwidth B_S =B/M and K of M sub-bands which contain non-zero signal are to be transmitted. In Figure 3, the signal is first modulated in individual bands and then an N/M point [[~~FFT~~]] IFFT is applied to each individual band to get the time domain signal. The time domain signal is further upsampled to the desired sampling rate and a bandpass filter is applied to put each sub-band signal into the right location in the total frequency band. The receiver shown in Figure 4 is the reverse operation of the transmitter shown in Figure 3. The signal is first filtered into individual bands and then down sampled. N/M point FFT is applied to each sub-band signal and data is ~~received with~~ retrieved using QAM demodulation. --

Please replace the paragraph beginning at page 4, line 3 with the following amended paragraph:

-- Although in the above scheme, the same bandwidth is assumed for all subbands, ~~variable~~ the bandwidth may vary from one subband to another, with a corresponding variation of ~~with variable~~ FFT size and (up/down) sampling rates~~ can be handled as well~~. As for the FFT size and filter selection, two different schemes can be used, as described next. --

Please replace the paragraph beginning at page 4, line 26 with the following amended paragraph:

-- The second scheme is discussed next where signals can be located in any frequency band [F_1, F_2]. In this second scheme, FFT is applied to only single sideband spectrum and the other half can be recovered using the symmetrical property. Figure 7 and Figure 8 show the transmitter and receiver structures which are very similar to the architecture of Figure 3 and Figure 4. The main difference between the schemes is that down/up sampling by M is replaced with down/up sampling by 2M. Also since we are dealing with single side band signal, the filter used is a single side band complex filter and the size of FFT is a N/(2M). --

Please replace the paragraph beginning at page 5, line 1 with the following amended paragraph:

-- Figure 9 shows the signal spectrum of the second scheme for the single sub-band of Figure 7. In this scheme the signal is located in any frequency band [F_1, F_2]. Figure 9(a) is the sub-band spectrum which is to be transmitted in the total frequency band. Figure 9(b) is single side band signal of Figure 9(a) and Figure 9(c) is its down sampled version. Starting with the base band of Figure 9(c), which is again shown in Figure 9(d) QAM modulation and IFFT are applied to data based on the spectrum requirement of Figure 9(d). Figure 9(e) is the up sampled spectrum and the dashed lines shows the filter with the proper frequency response to get the right single side band signal spectrum of the total frequency band, which is again shown in Figure 9(f). It is to be noted that the signal spectrum is no longer symmetrical and as a result, both the time domain signal and filter are complex numbers. By taking the real part of the filter output, the symmetrical spectrum of Figure 9(a) is obtained. Since only the real part of the filter output is transmitted, the computation requirement for the complex filter operation is halved. Also, since FFT is only applied to the single side band spectrum, the size of the FFT is half of that in Figure 5. --

Please replace the paragraph beginning at page 5, line 16 with the following amended paragraph:

-- Figure 10 shows the receiving spectrum of the same sub-band. Figure 10(a) is the receiver signal spectrum together with the other sub-band signal. The dashed line shows the frequency response of the filter to get the proper single side band signal as shown in Figure 10(b). Again, since the input signal is real with a symmetrical spectrum and the single band filter is complex, the computation requirement for the complex filter operation is halved. Figure 10(c) shows the down sampled signal spectrum, where FFT and QAM demodulation are applied to the based band signal in the period [-π, π] to get the receive data. The spectrum in one period [-π, π] is also shown in Figure 10(d). --